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Power System Design

GP 16-02-01

Scope

[I] This Global Practice (GP) covers the design of power distribution systems. Power supplies to Instrumentation and other essential services are covered by [GP 16-08-01](#).

[I] Utility supply company negotiations with regard to billing, plant operation, supply voltages and capacity, and similar details shall be handled by the Owner's Engineer.

[I] An asterisk (*) indicates that additional information is required. If a job is contracted, this additional information is furnished in the Job Specification.

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1. Required References

[I] This Section lists Practices and Standards that are generically referenced and assumed to be a part of this document. Unless otherwise specified herein, use the latest edition.

1.1. Global Practices–ExxonMobil Engineering Practices

GP 14-03-01	Fireproofing
GP 15-07-03	Alarm Systems
GP 15-09-02	Electric Motor Operators for Valves
GP 16-08-01	Instrument and Essential Services Power Supplies
GP 16-12-01	Switchgear, Control Centers, and Bus Duct

2. Additional Requirements

* [I] The following Publications and Standards shall be used with this GP as specified by the Owner's Engineer. Additional or equivalent standards of design may also be specified by the Owner's Engineer.

2.1. IEC–International Electrotechnical Commission

IEC 60034-1	Rotating Electrical Machines - Part 1: Rating and Performance
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2.2. IEEE–Institute of Electrical and Electronic Engineers

IEEE 141	Recommended Practice for Electric Power Distribution for Industrial Plants IEEE Red Book
IEEE 242	Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems
IEEE 835 INTRO	Standard Power Cable Ampacity Tables

2.3. ISA–The Instrumentation, Systems, and Automation Society

ISA 18.1	Annunciator Sequences and Specifications
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2.4. NEMA–National Electrical Manufacturers Association

NEMA C84.1	Electric Power Systems and Equipment - Voltage Ratings (60 Hertz)
NEMA MG 1	Motors and Generators

2.5. NFPA–National Fire Protection Association

NFPA 70	National Electrical Code
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2.6. Other Publications

Current Rating Standards for Distribution Cables, 69-30, ERA Technology
EMRE Program 3317 (PC Magnet) User Manual
Transactions on Industry and General Applications Allowing for Decrement and Fault Voltage in Industrial Relaying, IEEE, Mar./Apr. 1965 pp. 130 – 139.

3. Definitions

Term	[I] Description
acceptable and preferred practices	* Where this GP lists more than one type of equipment or method as acceptable, the Contractor shall make the selection based on total installed cost. Where one particular type of equipment or method is listed as preferred, it shall be selected provided it is lower or equivalent in total installed cost to other acceptable types or methods. Optimum cost benefits may be achieved by reducing maintenance and operating expense through initial added investment. Economic basis for calculating optimum cost benefits will be included in the general job specification. Owner's Engineer shall approve alternative choices.
adjusted maximum demand based on firm load data	Equal to 1.0 times maximum demand.
adjusted maximum demand based on non-firm load data	Equal to 1.05 times estimated maximum demand.
captive transformer	A transformer that supplies a single utilization device, usually a large motor.
demand factor	The ratio of the maximum demand of a system, or part of a system, to the total connected load of the system, or part of the system, under consideration.

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Term	[I] Description
firm load data	The load data derived from actual equipment performance characteristics and duty cycles for existing facilities.
lighting transformer	A transformer that mainly supplies lighting but may also supply convenience receptacles and other non-critical low voltage loads.
load factor	The ratio of the average load over a designated period of time to the peak load occurring in that period.
motor continuous overload capability/service factor	A multiplier which, when applied to the rated power, indicates power loading which may be carried continuously without exceeding by more than 10°C at continuous overload / service factor loading rated temperature rise per NEMA MG 1 or IEC 60034-1, if rated voltage and frequency are maintained. When the motor is operated at any service factor greater than 1.0, it may have efficiency, power factor and speed different from those at rated power, but the locked rotor torque and current and breakdown torque will remain unchanged
secondary-selective substations	Secondary-Selective Substations have two busses, each supplied by a normally-closed incoming line circuit breaker and connected together by a normally-open bus tie circuit breaker. (As used herein, the term secondary-selective is applicable to dually fed substations with or without transformers.) The dual sources normally divide the load in non-paralleled operation. Upon failure of one source, the substation is isolated from the failed source and the deenergized bus section is connected to the source remaining in service. This transfer of load may be manual or automatic.
spot-network substations	Spot-network substations have two or more busses, each supplied by a normally-closed incoming line circuit breaker from synchronized sources and connected together by normally-closed bus tie circuit breaker(s). Upon failure of one source, the substation is isolated from the failed source by automatic operation of protective relaying, e.g., directional overcurrent, differential.
sub-bus	A substation bus which is directly supplied (without an intervening transformer) from the switchgear main bus. Examples of sub-busses are motor control and turnaround power center busses.
the 15-minute maximum demand of loads	The greatest average load that can occur for a 15-minute period.
the 8-hour maximum demand of loads	The greatest root-mean-square value the load can take during any 8-hour period. It is the equivalent thermal aging load.



Term	[I] Description
undervoltage protection	As applied to motor control, causes the motor controller to trip either instantaneously or after a predetermined time interval upon a dip or loss of motor supply voltage. Upon restoration of normal supply voltage, the controller does not reclose or only recloses if supply voltage is restored within a predetermined time interval.
undervoltage release	As applied to motor control, causes the motor controller to trip instantaneously upon a dip or loss of motor supply voltage and to reclose instantaneously upon restoration of normal supply voltage, regardless of the time duration of the voltage dip or loss.
voltage drop	The difference between the voltages at the transmitting and receiving ends of a feeder, main, or service. With alternating current, the voltages are not necessarily in phase and hence the voltage drop is not necessarily equal to the algebraic sum of the voltage drops along the several conductors

4. Documentation

- 1) [O], [M] A simplified overall system one-line diagram(s) shall be provided showing all substations and interconnections.
- 2) * [O], [M] A one-line diagram shall be provided for each substation and shall cover all power circuits and excitation circuits including metering and protective relaying. All one line diagrams shall be a separate set of drawings; they shall not be located on other types of drawings. A typical one-line diagram showing style used by Contractor shall be submitted to the Owner's Engineer for approval prior to starting the drawings. Each substation's diagrams shall include the following information:
 - a) Major equipment ratings as indicated in Table 1.
 - b) Number and connections of current and potential transformers.
 - c) Connection of power transformer windings (such as wye or delta), type of neutral grounding.
 - d) Relay description including ANSI device number and number of devices.
 - e) Dotted lines to associate the major protective relays with the auxiliary relays or primary circuit devices which they actuate, using arrows at the ends of these lines to point to the devices operated.
 - f) Maximum and minimum short circuit levels on which design was based.
 - g) Identification and size of individual loads connected to each switchgear, motor control center, turnaround power center, and switchrack bus.
 - h) Reacceleration step number for each motor provided with automatic reacceleration control.
- 3) [O], [M] Diagrams shall be furnished as indicated below. Vendors' drawings shall be used to the maximum extent practical when providing this information; however, typical engineering schematics and wiring diagrams shall not be used without Owner's Engineer's approval.

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- a) A Contractor or Vendor prepared internal connection diagram shall be provided for each piece of equipment. These connection diagrams show wiring within each piece of equipment and are not a substitute for interconnection diagrams.
- b) Schematic/elementary logic diagrams shall be furnished for the control circuits of motors and other equipment. Each motor or device being controlled shall have all associated controlling devices shown on a single drawing.
- c) * Interconnection/point-to-point diagrams shall show the same terminal numbers and device and conductor designations that appear on the connection diagrams. They shall also indicate locations of terminals if the equipment has terminals in more than one location. Contractor shall prepare sample interconnection wiring drawings for Owner's Engineer's review and approval prior to proceeding with basic design.

Table 1: Major Equipment Ratings

Major Equipment	Ratings to be Shown on One-Line Diagrams
Generators	V, kW, PF, X"d, X'd, Xd
Power Transformers	kVA (OA/FA), V, tap range, impedance, BIL if arresters applied at same voltage
Circuit Breakers	Continuous A, interrupting MVA or kA at system nominal voltage, momentary kA if different from interrupting, BIL if arresters applied at same voltage (Specify whether symmetrical or asymmetrical basis used for kA ratings)
Bus	System nominal V, Continuous A, Momentary kA (specify symmetrical or asymmetrical basis)
Arresters	kV operating
Neutral Grounding Devices	A (short time and continuous ampere rating), Ohmic value
Current Transformers	Ratios, Accuracy Class
Potential Transformers	Ratios
Cable and overhead lines supplying power-transformers and substation busses	Size, Type, Current Rating

4.1. Data

- 1) [O], [M] Contractor shall prepare the following data and shall use these data as the basis for sizing system components, checking system performance, and setting system protective relays and devices:
 - a) Load Data
 - b) Short Circuit Data
 - c) Voltage Profile Data
 - d) Motor Heating Data

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- e) Cable sizing basis
- f) Relay data

* Contractor shall furnish copies of all data for approval by Owner's Engineer. After approval, Contractor shall furnish final copies to Owner's Engineer.

A summary of the results and description of the system conditions used as the basis for the data calculations shall be provided with each set of final load data, short circuit data, and voltage profile data.

- 2) * [I] Machine calculations shall be used to prepare the following data using software specified or approved by the Owner's Engineer:
 - a) Load data
 - b) Short circuit data
 - c) Voltage profile data
 - d) Motor heating data
- 3) [I] Contractor is responsible for problem formulation, all data verification, de-bugging, and confirming that output is in accordance with project design requirements. Preferred tools include PTW32, ETAP, and PSS/E (others require approval of Owner's Engineer). EMRE Program 3317 and User Manual will be made available to the Contractor by the Owner's Engineer, if needed.
- 4) * [R] Short-circuit data shall be accompanied by one-line diagram with busses identified to match the computer results.

Summary of results shall include the following data on computer generated one-line diagrams or in tabular form:

- a) Short circuit currents on each bus and line used to establish the interrupting and momentary ratings of circuit breakers, fuses, and other switching devices at busses and lines.
 - b) Maximum and minimum symmetrical and asymmetrical short circuit currents at each bus and line used in establishing settings for the protective relays and devices.
- 5) [I] Load data and short circuit data shall be furnished by the contractor to the Owner's Engineer on at least two occasions:
 - a) Before major electrical equipment (such as power transformers and switchgear) is purchased.
 Note: These issues of data are preliminary and need only be complete and accurate enough to verify that proper equipment ratings such as circuit breaker interrupting and momentary duties and transformer self and forced-cooled ratings have been specified.
 - b) When one-line diagram is presented for final approval and loads are final.
 - 6) [I] Voltage profile data shall include:
 - a) Voltage variations at busses and motor terminals during normal operation.
 - b) Voltage variations at busses and motor terminals during motor starting and reacceleration, whichever governs, with all sources in service and with the largest source out-of-service.
 - c) Loading of bus supply lines in amperes during motor reacceleration.
 - d) Motor reacceleration schedule showing motors assigned to each step.
 - e) Tap settings for all power transformers.

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- 7) [R] Motor heating data shall show the rotor temperature rise during starting of each squirrel cage induction motor larger than 1500 hp (1100 kW) under design starting conditions and during full-load operation.
- 8) [R] Cable sizing basis shall be furnished, covering implementation of the requirements of this GP with respect to:
 - a) Ampacity rating basis including factors such as conductor temperatures, load factors, earth thermal resistivity, and ambient earth and air temperatures.
 - b) Ampacity derating basis including derating factors for cable grouping, spacing, proximity to high temperature equipment, effect of protective coverings for fireproofing, sheath currents, and operating temperature of cable termination and device terminal.
 - c) Sizing basis to meet voltage drop limitations during normal operation and during motor starting or reacceleration.
 - d) Sizing basis to meet short circuit withstand.
 - e) Neutral sizing to include the effect of harmonics.
 - f) Adequacy of cable shields to carry ground fault current.
 - g) Adequacy of cable shield terminations to carry circulating currents, when single-phase cables are used and shields are grounded at both ends. Maximum expected shield currents shall be indicated.
- 9) [R], [M] Relay data shall be furnished for each adjustable relay or other protective device as follows:
 - a) Device symbol number, circuit to which applied, and device's instrument transformer (if any) ratio and accuracy class.
 - b) Device identification including manufacturer model number, time characteristic, and ampere or voltage range.
 - c) Device setting, calibration point, and one or more check points.
 - d) Logic diagrams when relay contains programmable logic.
 - e) Manufacturer's application literature for each type relay supplied.

Data shall also include settings for auxiliary relays and devices, such as timers, associated with each protective device.
- 10) * [M] Tabular form shall be used to present relay data. Additional columns shall be provided for recording actual test values (voltage, current, and time) corresponding to calibration and check points resulting from field setting, calibration, test, and comments. Sample relay data forms and coordination curves shall be submitted to the Owner's Engineer for approval prior to beginning relay coordination study documentation.
- 11) [M] Microprocessor-based relays require full printouts of all parameters and programmed logic contained within the relay. Relay settings shall be supplied in computer file format when settings comprise more than one page of text. When custom logic is programmed within the relay, a narrative shall be provided describing the functions provided.
- 12) * [R], [M] Coordination curves shall be included with the relay data. A set of curves matching plant practice shall be furnished for each voltage level showing the time vs. current (or voltage) curves for all phase relays and other phase protective devices at their specified settings. A separate but similar set of curves shall be provided for all ground relays and other ground protective devices. Symmetrical maximum and minimum short circuit levels shall be shown on each set of curves. When

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specified, Contractor shall utilize the relay coordination software specified by the Owner's Engineer to present the coordination curve results.

The protective device coordination shall include the following:

- a) For voltage levels supplied through transformers:
 - i) Transformer primary overcurrent protective device curves plotted in terms of secondary current.
 - ii) For delta-wye transformers, allowance for the higher current in one primary phase (16 percent higher than equivalent secondary phase current) during secondary phase-to-phase faults.
 - iii) Transformer through-fault withstand point for maximum three-phase secondary faults; also, withstand points for other types of secondary faults if more limiting than three-phase fault.
 - b) For secondary-selective substations with automatic transfer:
 - i) Coordination between the transfer initiating undervoltage relays and the incoming breaker overcurrent relays (see IEEE Transactions on Industry and General Applications, Mar./Apr. 1965, pp. 130 to 139 for method).
 - ii) Settings of the instantaneous overcurrent and undervoltage relays used to block automatic transfer.
 - c) For substations using time-undervoltage relays for motor undervoltage protection, the coordination between overcurrent relays and motor undervoltage relays (see IEEE reference, Item b above, for method).
 - d) Coordination curves for the protective relaying of each motor rated above 1000 volts including locked rotor damage points. One curve sheet may be used for services having motors of the same ratings, locked rotor damage points, and with the same relaying.
 - e) For feeder cables supplying busses and power transformers, the safe insulation heating limit (short circuit withstand) curve for the cable plotted on the same curve sheet with the feeder protective device curves.
 - f) Emergency generator and UPS systems.
- 13) [O] Decrement effects shall be shown in the relay coordination if in-plant generation contributes to faults. Method of showing response of inverse time relays to decrement shall be as given in IEEE Transactions on Industry and General Applications, Mar./Apr. 1965, pp. 130 to 139.
- 14) [I] Relay coordination curves shall be furnished on two occasions:
- a) Before current transformer ratios and relay ranges and characteristics are specified to the supplier.
Note: This issue of the coordination is preliminary and need only be complete and accurate enough to verify selection of proper ratios, ranges, and characteristics.
 - b) When Relay Data is presented for final approval.
- 15) [I] Generator data shall be furnished for salient pole generators larger than 500 kW. These data shall consist of:
- a) Direct and quadrature axis subtransient, transient, and synchronous reactances.
 - b) Negative and zero sequence impedances.
 - c) Decrement curves for three-phase and phase-to-phase faults, with generator operating at full load and with exciter under control of voltage regulator. If not available, furnish decrement curves for

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